

# **Ongoing sedimentological and palaeoecological investigations at Nyabuiyabui wetland, Kiptunga Forest Block, Eastern Mau Forest, Nakuru District, Kenya**

A report to the Mau Forest Conservation Office, Kenya Forest Service, and the National Museums of Kenya Palaeobotany and Palynology Section.



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Further information can be found at <http://www.real-project.eu/nyabuiyabui-swamp-fieldwork>

**Cover photo:** Nyabuiyabui wetland facing northeast from the road (Joseph Mutua and Colin Courtney Mustaphi, 12 April 2014).

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## **Abstract**

This report summarizes fieldwork done by members of the REAL project who are studying wetlands across Kenya to understand how these systems have evolved through time. We employ sedimentological and palaeoecological approaches to physically characterise the wetland basins and to gain a deeper understanding of how these wetlands have changed in response to past variability of climate and human land use practices. Multiple wetlands exist within the Mau Forests of Kenya that are ecologically and developmentally important to the region. Hydrologically, these swamps form significant surficial reservoirs of water that drain into extensive channel networks across East Africa and are an important component of the high elevation ‘water towers’ that are crucial to water management and the political imagining of nationally-important water resources. Historically, these wetlands have been key landscape features serving wildlife, livestock, and human populations with water particularly during dry periods. Few paleoenvironmental studies have been produced on the Mau Escarpment. The purpose of this study is to investigate these wetlands and examine how these ecosystems have responded to Late Quaternary climatic variability, large wildlife herbivory, and changes in human land use patterns. Continued scientific study is needed due to the diversity of wetland ecosystems across this landscape with strong environmental gradients and to analyse the varying spatial controls influencing the environmental conditions. This is especially true considering the multiple, recent, rapid and intense landscape transformations that have occurred. Some of these transformations include the industrial management of plantation forests, channelisation of wetlands, sediment infilling, road construction, increasing human populations, and conversion of forest to farmland. This document reports ongoing scientific study of the physical wetland systems and how the sites have evolved over geological time scales in response to climatic and land-use behavioural changes.

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## List of Acronyms

asl	above sea level
GPS	Global Positioning System
ITCZ	Intertropical Convergence Zone
ITN	Initial Training Network
KFS	Kenya Forest Service
NACOSTI	[Kenya] National Commission for Science, Technology and Innovation
NMK	National Museums of Kenya
REAL	Resilience in East African Landscapes, Marie Curie ITN project

## 1.0 Introduction

### 1.1 Purpose and Scientific Approach

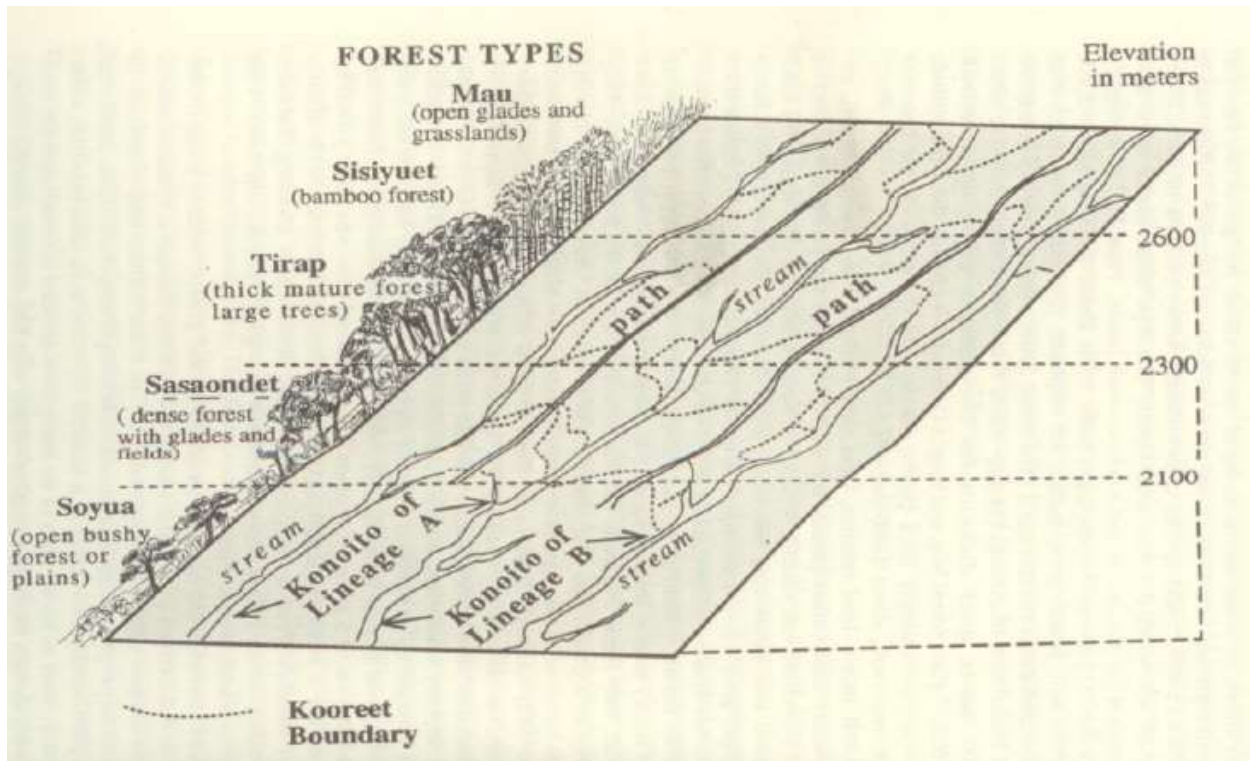
This report describes some preliminary fieldwork undertaken as part of a larger project entitled ‘Resilience in East African Landscapes: Identifying critical thresholds and sustainable trajectories – past, present and future (REAL)’, a Marie Curie Initial Training Network funded by the European Commission. This project aims to use a multi-disciplinary approach to examine the ontogeny of East African landscapes and understand the important drivers of environmental change and the interactions between natural ecosystem processes and the impacts of anthropogenic activities (Gelorini and Verschuren, 2012). To improve our understanding of human-environment interactions we make use of multiple investigatory approaches to reconstruct and critically examine past environmental changes using techniques from earth sciences, archaeology, historical and anthropological research, that will be useful for informing sustainable development initiatives and planning (Marchant *et al.*, 2010; Marchant and Lane, *In press*).

### 1.2 Regional Setting

The Mau Forest complex is the largest forest block in the country and the largest single block of closed canopy forest in East Africa at 400,000 ha (Nkako *et al.*, 2005; Spruyt, 2011). It is one of Kenya’s five main ‘water towers’ and is located on the Mau Escarpment with elevations ranging from 1800-3000 m asl. The Mau Forest complex is a large, ecologically and economically important region that has sustained human communities, such as the Ogiek who are among the oldest indigenous inhabitants of the area. Other communities include the Nandi, Kipsigis, Maasai and Kikuyu that also inhabit the landscape. It is a strategic natural resource for timber extraction since the 1930s under management by the Kenya Forest Service. KFS regulates and manages resource extraction and the current framework is that logging companies pay for permits and licenses to log in specific plantations planted by the KFS to meet the timber demand. It is coordinated by the KFS and tactically individual blocks are monitored by trained foresters and forest rangers monitor movement within the forest block. Much of the forests were cleared for settlements and small to medium sized holder farming during the 1970s under President Moi.

The region is relatively mesic experiencing bimodal rainfall with an annual average of 2000 mm. Annual total precipitation ranges 1200-1600 mm (Kenya’s Natural Capital - A Biodiversity Atlas, web version). Rainfall increases with elevation while temperatures decrease (Lambrechts, 2005). The Western Mau Forest Block receives higher rainfall (>2000 mm). Most precipitation is derived from the Indian Ocean and the bimodal rainfall is influenced seasonally by the position of the ITCZ and over multi-annual scales by El Niño Southern Oscillation and Indian Ocean Dipole teleconnections (Marchant *et al.*, 2006). The area experiences cold

temperatures as low as 0 °C. Topographic relief ranges from 1800 m to >2900 m asl. There are six major vegetation zones that are largely controlled by orographic climate. The zones include open bushy forest below 2100 m, dense forest with glades between 2100-2300 m, thick mature forests from 2300-2600 m, bamboo forest also exist around 2600 m, and open glades and grasslands >2600 m (summarized in Kratz, 1994).



**Fig 1.0:** Generalised vegetation zones (adapted from Kratz, 1994).

### *1.3 Study region: Kiptunga Forest Block*

Kiptunga Forest Block is located in the Eastern Mau Forest Block, Mau Narok County, Nakuru District, and covers an area of 10360.20 ha with an average elevation of 2865 m asl. The forest vegetation is frequently zoned into indigenous forests, plantations, bamboo, and grassland on 1:50 000 topographic maps. Seasons are not predictable and rainfall is heavy and erratic. Soils are humid climate Andisols (suborder: Udands) containing volcanic tephra and are relatively young and productive (Kenya's Natural Capital - A Biodiversity Atlas, web version). The main crops grown in this region are wheat, barley, potatoes and peas. The soils are productive but fertilizers are used to increase yields. Kiptunga Forest Block has been managed by forester Mr. Dennis Mbogo since 1 September 2010 and the forest station is located at 00°27.368' S, 035°47.829' E (Figure 1.2) at an elevation of 2927 m. The station also has local precipitation records. Foresters have continually operated in the Kiptunga Forest since the first forester's tenure ended 9 November 1959 (Appendix 1). The forest is inhabited by the Dorobo/Ogiek community who are hunter-gatherers but slowly transferring to farming practices. Kiptunga Forest has a wildlife population that includes birds, antelopes, gazelles, and hyenas. Land

excision was carried out in 1997-1998 giving land to the local community and reducing the forested area. The main threat that the forest faces is illegal settlement that occurred from illegal extension of neighbouring group ranch boundaries. Due to household energy demand, there is illegal burning of charcoal in the forest. Charcoal production is legal on private farms.

#### *1.4 Study site: Nyabuiyabui Swamp*

The Nyabuiyabui swamp located at 0° 26' 11.28" S, 35° 47' 58.74" E; 2920 m asl (Figure 1.4) expands and contracts due to hydroclimatic conditions. *Nyabuiyabui* is a Dorobo word meaning 'spongy' (Spruyt, 2011) or 'marshy, bog like'. It is located on Kenya 1:50 000 map sheet 118/4 (Survey of Kenya) and 1:10 000 map sheet of the Forest Plantation Map Eastern Mau Sheet No. 12 and 13 (Photomap; Appendix 3 and 4). The wetland covers an area of 122 ha and the current wettest area is about 6 ha. Logging roads have been constructed on the western and southern sides of the wetland (Figure 1.3). There are several rivers/streams that flow from this headwater wetland and the possibility of groundwater seepage from the swamp (Table 1.1). Nyabuiyabui Swamp is the source of rivers Mara, Rongai, Sondu and streams flowing to Lakes Victoria, Nakuru and Baringo. The swamp is shallow with most water depths well below 50 cm. The water level has been decreasing and some locals mentioned that there was open water within the swamp and channelized to the road bridge prior to 1972. The road bridge is located at S 00°26.246' E 035°47.859' at an elevation of 2926 m. There is some evidence of recent human modifications of the swamp including the bridge construction over an outlet channel, a cut line along the western margin (Photomap, 2008), an abandoned, government-built pumping station immediately to the east of the bridge, and cattle grazing along the dry margin.

It is currently continuously covered by Cyperaceae-Poaceae dominated vegetation and surrounded by *Juniperus* along the southern margin and monoculture tree plantations in the immediate landscape (Figure 1.5). The forest office maintains records of plantation histories and forest fires. The area is rated as a low fire area with most fires occurring as spot or localised fires. Common indigenous tree species are *Podocarpus*, *Juniperus*, *Olea* spp., *Dombeya*, and *Hagenia*. *Dombeya* is an important tree to Dorobo people as it is frequently associated with honey harvesting. The most common exotic tree species are *Pinus*, *Cupressus*, and *Eucalyptus*, which were mainly grown for commercial logging from as early as 1935 (Table 2). Exotic species are the preferred plantation species as they grow quickly to meet the industrial timber market. Millers are licensed to extract timber from the exotic plantations which earns the government revenue through the KFS. Pest outbreaks, such as rats and moles, are common in the plantations; monkeys also damage the *Pinus* and *Cupressus* plantations at the apical buds. The swamp is in an area prone to forest fires due to the surrounding grassy area; although, the relatively wet forest does not burn frequently. Pastoralists burn pasture areas around the swamp margin before the rainy season to eradicate pests and improve pastures.





**Figure 1.1:** Location of Nyabuiyabui swamp site in Nakuru District, central-west Kenya.



**Figure 1.2:** Kiptunga Forest Block forester station (KFS; photograph: Colin Courtney Mustaphi)



**Figure 1.3:** Panorama of Nyabuiyabui Swamp, facing northeast (left side) and east (right side) from the logging road (Photographs: Colin Courtney Mustaphi, 12 April, 2014).





**Figure 1.4:** Nyabuiyabui wetland (center) and surrounding landscape within the managed plantations of Kiptunga Forest Block.



**Figure 1.5:** Typical Cyperaceae, Poaceae and other vegetation at the drier margin of the swamp (top) and Cyperaceae-Poaceae typical of the wet center of the swamp (bottom).

**Table 1.1:** Drainage of the headwater Nyabuiyabui Swamp.

Hydronym	Flow Direction	Notes
Marishoni	N	
Rongai	E then N	
Kiptunga	SE then S	Tributary of Nyabuiyabui
Nyabuiyabui	SW then S	
Songi	W then SW	

Rivers flowing from Nyabuiyabui and the lake basins:

- River Sondu – Lake Victoria.
- River Mara – Lake Victoria.
- Southern Ewaso Ng'iro – Lake Natron.
- River Molo – Lake Baringo.
- River Njoro – Lake Nakuru.
- Nderit River – Lake Nakuru.
- Makalia River (now dry) – Lake Nakuru.
- Naishi River – Lake Nakuru.

**Table 1.2:** Exotic tree plantations surrounding Nyabuiyabui (Photomap, 2008).

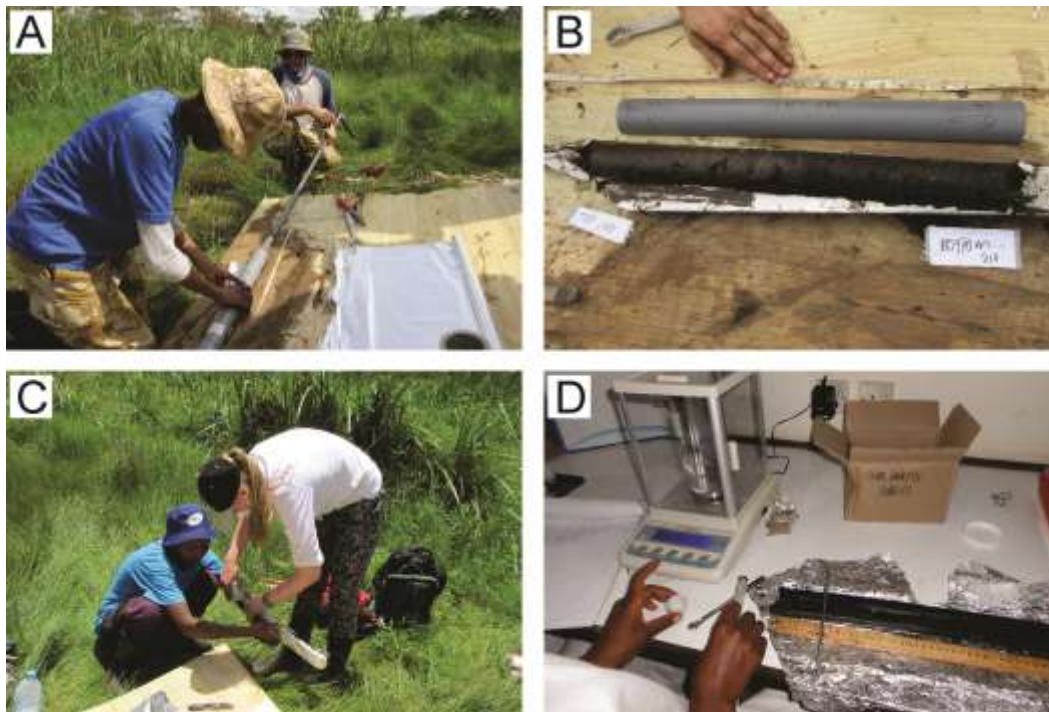
Acronym	Species	Family	Origin	Common name	Area (ha)	Years planted
P. PAT.	<i>Pinus patula</i>	Pinaceae	Mexico	spreading-leaved pine, Mexican weeping pine	46.5	1962, 1968, 2004
CUP. LUS.	<i>Cupressus lusitanica</i>	Cupressaceae	Mexico, Guatemala, El Salvador, Honduras	Mexican White Cedar	303.8	1968, 1977, 1978, 1980, 1981, 2004, 2006
EUC. MAC.	<i>Corymbia maculata</i> (syn. <i>Eucalyptus maculata</i> )	Myrtaceae	eastern Australia	Spotted Gum	5.2	1978, 1981
CED. NVE. OLIVE				Pencil cedar?	36.6	1935-1938
Unknown					8.6	
Other					28.8	
Total					429.5	



## 2.0 Methods

### 2.1 Field Methods

Vegetation surveys, sediment coring (Figs. 2.1, 2.2, 2.3, 2.8), and placement of pollen traps (Fig. 2.4, 2.5, 2.6), and sediment depth profiling (Fig. 2.7), were undertaken at Nyabuiyabui Swamp from 10-12 April 2014. A Russian Corer was used to collect the sediment stratigraphies in 50-cm drives that overlapped by ~10 cm to ensure the full stratigraphy was represented. A 514 cm core was recovered from S 00°26.188' E 035°47.978' at an elevation of 2919 m for sedimentological and palaeoecological analysis. Cores were wrapped in plastic and aluminum foil (Fig. 2.2 C) and stored at the National Museums of Kenya. Surface samples of the uppermost 2 cm of the sediments were collected in Whirl-pak bags® from the coring sites as well as most pollen trap locations. Pollen traps, following the Behling design (Behling *et al.*, 2001; Jantz *et al.*, 2013; Schüller *et al.*, 2014; Fig. 2.4), were deployed within and surrounding the swamps to characterise the spatial variability of the modern pollen rain and to assess vegetation-pollen relationships (Fig. 2.6). Deployment locations were chosen to cover the variability of vegetation surrounding the wetlands and GPS coordinates recorded. The traps were assembled at the National Museums of Kenya using 75 mL Fisherbrand™ centrifuge tubes, which contained 5 mL of glycerol and a wad of synthetic cotton wool stuffing, strapped to 50 cm or 1 m long wood stakes (Fig. 2.5).



**Figure 2.1:** **A)** Sediment core extrusion in the field, **B)** Core section ORM 2E of the sediment stratigraphy from 160-210 cm depth. **C)** Wrapping of the cores in plastic and aluminum foil for storage and shipping. **D)** Laboratory work on sediments at the National Museums of Kenya, Palaeobotany and Palynology Section, Nairobi. Photographs: A-C Esther Githumbi, D Colin Courtney Mustaphi (Courtney Mustaphi *et al.*, 2014).

## 2.2 Laboratory Methods and Future Analyses

The recovered sediments will be used for sedimentological investigations and vegetation reconstructions using pollen analysis (Fægri and Iversen, 1989; Moore *et al.*, 1991), plant macroremains, and charcoal analysis (Whitlock and Larsen, 2001). Laboratory analyses to characterise the sediments and understand the depositional environment will include determination of detailed lithology, bulk density, organic and inorganic content, magnetic susceptibility and radiocarbon dating. An exotic marker, for example *Lycopodium* spores, will be added prior to pollen analysis to aid in calculation of absolute concentrations (Stockmarr, 1971). This analysis will provide samples needed for the identification and enumeration of the pollen, spores and charcoal. A 1 cm<sup>3</sup> subsample interval will be used and concentration quantified as abundance (number of particles per unit of volume). The analysis will be carried out at a magnification of ×400 to ×1000 and from each slide a minimum of 400 pollen grains, excluding Poaceae and Cyperaceae, will be counted. Pollen grains will be identified using published references and a reference collection at the National Museums of Kenya.

The study will provide a lithological description (Figure 2.8) of sediments from the different sites and a chronology providing dates at different levels which will be important in time periods for the occurrences of the different variations such as changes in climate, introduction of exotic species, human impacts like burning, grazing and agriculture. The water level appears to have varied in the past as evidenced by a quick survey of the local geomorphology and distribution of plants. An analysis of maps and air photography and sedimentological measurements should provide additional insight into past water levels. Charcoal analyses (Conedera *et al.*, 2009) will provide insight into the history of biomass burning in the region and be used to assess the dominant controls of the fire regimes during the geologic past (Whitlock *et al.*, 2010; Bowman *et al.*, 2011). Long term vegetation records from the pollen will be used to assess changes in the ecosystem and the influence of climate change and human activities will be obtained. A fire history record from the charcoal data will also be acquired and analysed. The pollen and charcoal data will also be used to identify the occurrence of large disturbance events if any and the responses which is important in trying to predict future ecosystem responses to similar events. The data will give evidence of ecosystem changes experienced in the past and help us understand the major drivers of environmental change in the region.

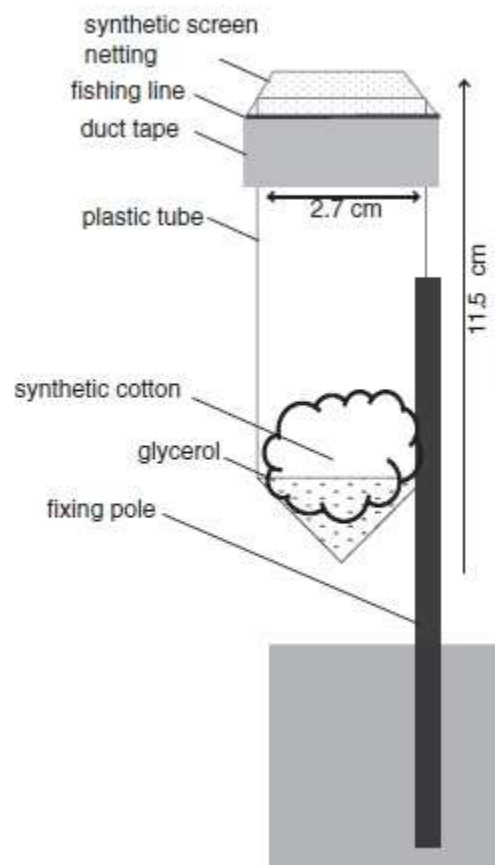


**Figure 2.2:** Coring the deeper sediments on 11 April 2014 at the swamp center (Photograph: Esther Githumbi).



**Figure 2.3:** Core drive NB8 with sediment stratigraphy from 304-354 cm deep (Photograph: Esther Githumbi).





**Figure 2.4:** Behling pollen trap design (adapted from Jantz *et al.*, 2013).



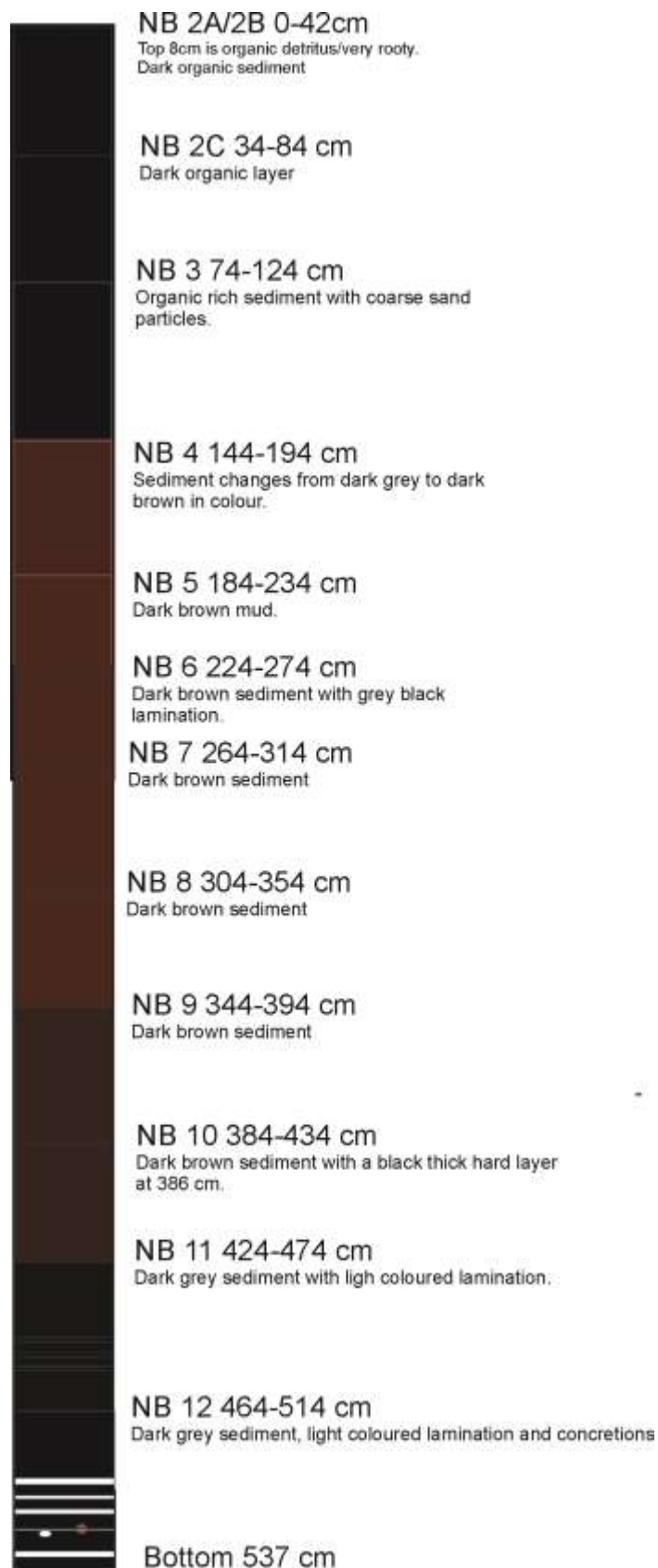
**Figure 2.5:** A) Main components of the Behling design pollen traps (Behling *et al.*, 2001; Jantz *et al.*, 2013), B) a completed trap, C) traps were shipped from the National Museums of Kenya covered in plastic, and D) a deployed trap. Photographs: A-C Colin Courtney Mustaphi and D Esther Githumbi (Courtney Mustaphi *et al.*, 2014).



**Figure 2.6:** Pollen trap deployment locations (yellow; Appendix 7) and coring location (red).



**Figure 2.7:** Transect of sediment depth measurements (yellow; Appendix 6) and coring location (red).



**Figure 2.8:** Nyabuiyabui stratigraphy and core drives.

### **3.0 Planned Outcomes and Scientific Contributions**

These datasets and interpretations will contribute to a PhD dissertation at the Environment Department, University of York, UK, and the results will be published in the peer-reviewed scientific literature and data made publicly available. To date, there have been few paleoecological studies near this region, which has a rich ecological and human-environment interaction history that requires multiple intensive studies to fully understand for making pragmatic and informed public policy and land management decisions. This information will contribute to our knowledge of the evolution of these ecosystems, the dominant earth system processes in operation that have been occurring in concert with the human land-use relationship with the landscape, and give us a stronger understanding of how these critically important wetland systems may respond to climate change and human land-use patterns in the future. Specific contributions are anticipated to our understanding of vegetation responses to climate variability and human activities in the Mau Narok forests during the Holocene, an understanding of the role of fire in influencing plant biogeography and diversity, in response to natural drivers of fire activity and human behavioural patterns, and insights into vegetation-pollen relationships to further understand plant land cover distributions in the pollen records. This study is an initial study into the paleoenvironmental history of high elevation areas of Eastern Mau Forest that may develop into a larger multi-site analysis.

### **Acknowledgements**

We thank County Forest Coordinator Samuel Mukundi, forester Dennis K. Mbogo (retired), and an anonymous askari for aid in accessing the wetland. We also thank three local men and volunteers from TimSales Ltd. for coring help. We thank the British Institute in East Africa (Nairobi) for logistical support. We also acknowledge Margaret Omoto (NMK) and Denis Odera of NACOSTI for help with export and research permits. This project is funded by a Marie Curie Initial Training Network through the 7<sup>th</sup> Framework Programme, European Commission.

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**Appendix 1:** List of foresters at the Kiptunga Forest Block KFS station

2	A.D. MATHUR	9-11-59 - 9-11-59
3	H.A. EVANS	25-1-60 - 28-3-61
4	R.I. BUTTON	28-3-61 - 22-9-61
5	J.M. WILLIAM	22-9-61 - 17-6-63
6	K.V. DULTON	17-6-63 - 24-7-63
7	J.M. NJEHA	24-7-63 - 4-12-63
8	G. KINUTHIA	4-12-63 - 15-7-64
9	D.H. GATHUA	15-7-64 - 19-11-64
10	G.K. NTUGUNA	19-11-64 - 8-2-65
11	M. KANGERI	8-2-65 - 12-7-66
12	F.N. NDUNGU	12-7-66 - 6-1-67
13	S.M. GITAH	6-1-67 - 1-4-67
14	S. CHAZIMA	1-4-67 - 4-4-67
15	H. NTUGIA	4-4-67 - 13-12-68
16	M.M. KAMANZA	13-12-68 - 1968
17	H.M. KAMAU	1968 - 1969
18	D. WANGAI	1969 - 3-10-69
19	E. OLILA	3-10-69 - 11-8-71
20	J.A.M. MADOYA	11-8-71 - 4-11-72
21	F.O. OBIERO	4-11-72 - 11-1-75
22	H.K. KIEMA	11-1-75 - 16-1-83
23	S.O. MATIWA	16-1-83 - 23-5-84
24	D.M. NDUNGU	23-5-84 - 1-7-85
25	K.G. ORWENYO	1-7-85 - 28-2-88
26	P.N. MURICHU	28-2-88 - 27-7-89
27	D.M.W. MURANTJA	27-7-89 - 17-12-92
28	D.K. TONUI	17-12-92 - 20-2-1995
29	J.K. NZWILI	20-2-95 - 28-8-95
30	K.K. THOIGO	28-8-95 - 24-5-2000
31	J.K. CHUMO	24-5-00 - 17-8-00
32	P.W. MISIKO	17-8-00 - 12-9-00
33	J.N. CHARANA	30-11-00 - 10-5-01
34	E.C. MWAMBAO	10-5-2001 - 28-10-03
35	D.O. ELB. DIV.	28-10-03 - 30-3-04
36	C.O. OCHIENG	30-3-04 - 11-6-04
37	J.K. KING'ORI	11-6-2004 - 1-9-2010
38	D.K. MBOGO	1-9-2010 -

Photograph: Esther Githumbi, 10 April 2014.



## Appendix 2: Annotated bibliography of some relevant publications

Mau Mau peasant revolts against British Colonialism 1952-56. Available at BIEA library.

Maloba, WO. 1993. Mau Mau and Kenya – An analysis of a peasant revolt. Bloomington, Indiana University Press, 228 pp.

## Appendix 3: Maps covering Nyabuiyabui

Map sheet	Year*	Publisher	Availability	Notes
<b>1:10 000</b>				
Forest Plantation Map Eastern Mau Sheet No. 12	1990, amended S.M. Sanya, Jan 2008 (AP: Feb 1990)	Photomap (k) Ltd.	Kiptuga Forest Block Forester office (KFS)	
Forest Plantation Map Eastern Mau Sheet No. 13		Photomap (k) Ltd.	?	
<b>1:50 000</b>				
118/4 Njoro 4 <sup>th</sup> ed.	1967 (AP: 1948, 1961)	Survey of Kenya	NMK archaeology	Contours incomplete

\*Year of map publication; AP, air photography flight paths shown on map.

## Appendix 4: Air photographs covering Nyabuiyabui

Flight path	Roll numbers	Year	Publisher	Notes
CPE/KEN/121	5157-5159 5137-5140	1948	RAF	5139 may not exist
V 13 A 1073	056-059	1961	RAF	May not be at the Bodleian Library
PP	5237 Maybe 6021	Feb 1990	Photomap	PP 529(?)7

### Appendix 5: Sediment and water depth measurement locations

ID	Latitude	Longitude	Elevation (m)	Water depth (cm)	Sediment Depth	Notes
	S00°26.212'	E035°47.905'	2921	15	n/a	First water level
	S00°26.199'	E035°47.940'	2917	0	375	
	S00°26.198'	E035°47.943'	2918	0	350	1 hard layer
	S00°26.198'	E035°47.946'	2919	0	326	
1	S00°26.226'	E035°47.870'	2920	0	66	Silty organic sediment.
2	S00°26.225'	E035°47.874'	2920	0	84	Silty organics, sedge/grass
3	S00°26.225'	E035°47.881'	2920	0	67	Silty organic ending in riverine sand. Sedge/grass
4	S00°26.223'	E035°47.888'	2921	0	56	Silty organic ending in riverine sand. Sedge/grass
5	S00°26.218'	E035°47.895'	2921	0	92	Silty organic ending in sand and gravel. Sedge/grass
6	S00°26.215'	E035°47.901'	2921	0	139	Clay, less organic turning gray. Sedge/grass
7	S00°26.213'	E035°47.905'	2921	0	169	Clay, less organic turning gray. Sedge/grass
8	S00°26.210'	E035°47.913'	2922	0	199	Inorganic clay ending in a thick clay layer. Sedge and grass dominated.
9	S00°26.202'	E035°47.908'	2922	0	226	Clay sediment, sedge/grass and Juncaceae.
10	S00°26.198'	E035°47.901'	2921	0	148	Clay sediment, sedge/grass and Juncaceae.
11	S00°26.196'	E035°47.892'	2921	0	121	
12	S00°26.194'	E035°47.888'	2920	0	55	Dry soil, sedge/grass dominated.
13	S00°26.217'	E035°47.918'	2919	0	245	Dark gray mud, sedge/grass dominated
14	S00°26.224'	E035°47.925'	2920	0	253	Dark gray mud ending in thick soft mud. Sedge/grass dominated
15	S00°26.230'	E035°47.928'	2920	0	256	Dark gray mud ending in thick soft mud. Sedge/grass dominated with Juncaceae
16	S00°26.237'	E035°47.931'	2920	0	220	
17	S00°26.207'	E035°47.919'	2920	0	258	Brown gray mud. Sedge/grass dominated.
18	S00°26.201'	E035°47.933'	2921	0	386	Fine clay with thin hard clay layer.
19	S00°26.197'	E035°47.945'	2920	10	400	Fine dark gray clay. Sedge/grass dominated.
20	S00°26.194'	E035°47.953'	2920	10	440	Fine clay. Sedge/grass

ID	Latitude	Longitude	Elevation (m)	Water depth (cm)	Sediment Depth	Notes
21	S00°26.194'	E035°47.958'	2920	10	440	Fine clay with thin hard layer.
22	S00°26.188'	E035°47.969'	2919	17	524	Fine clay. Sedge/grass dominated.
23	S00°26.188'	E035°47.978'	2919	19	615	Dark fine clay. Juncaceae dominated with sedges/grasses
24	S00°26.191'	E035°47.986'	2919	18	608	Dark fine clay, sandy/gravel bottom. Juncaceae dominated with sedges/grasses
25	S00°26.192'	E035°48.001'	2919	19	597	Dark fine clay. Juncaceae dominated with sedges/grasses
26	S00°26.188'	E035°47.018'	2919	15	596	Fine clay, sedge/ Juncaceae dominated.
27	S00°26.187'	E035°47.033'	2919	8	469	Fine clay, sedge/Juncaceae dominated. Two hard layers.

\*GPS elevation error = 10 m.

**Appendix 6: Surface sediment sampling locations**

ID	Latitude	Longitude	Elevation (m)	Notes
SURF 1	S00°26.226'	E035°47.870'	2920	Silty organic sediment
SURF 2				
SURF 3	S00°26.196'	E035°47.892'	2921	
SURF 4	S00°26.242'	E035°47.891'	2924	Near small building, cedar/grass/sedge
SURF 5	S00°26.232'	E035°47.954'	2929	
SURF 6	S00°26.235'	E035°47.995'	2930	
SURF 7	S00°26.231'	E035°48.025'	2928	Sedge/grass
SURF 8	S00°26.224'	E035°48.044'	2929	
SURF 9	S00°26.221'	E035°47.888'	2929	River bank
SURF 10	S00°26.190'	E035°47.959'	2928	
SURF 11	S00°26.197'	E035°47.940'	2928	Sedge
SURF 12	S00°26.218'	E035°47.922'	2927	
SURF 13	S00°26.199'	E035°47.903'	2927	
SURF 14	S00°26.178'	E035°47.889'	2926	Sedge/grass
SURF 15	S00°26.175'	E035°47.906'	2925	Grass
SURF 16	S00°26.176'	E035°47.923'	2927	Grass
SURF 17	S00°26.177'	E035°47.935'	2925	Sedge
SURF 18	S00°26.163'	E035°47.947'	2925	
SURF 19	S00°26.133'	E035°47.919'	2925	
SURF 20	S00°26.121'	E035°47.908'	2928	Sedge/grass/heath

## Appendix 7: Pollen trap deployment locations (12 April 2014)

ID	Latitude	Longitude	Elevation (m)	Notes
NB POL TRAP 1	S00°26.242'	E035°47.891'	2924	Near small building, cedar/grass/sedge
NB POL TRAP 2	S00°26.237'	E035°47.921'	2927	Organic top sediment layer/highly rooted
NB POL TRAP 3	S00°26.232'	E035°47.954'	2929	
NB POL TRAP 4	S00°26.235'	E035°47.995'	2930	
NB POL TRAP 5	S00°26.231'	E035°48.025'	2928	Sedge/grass
NB POL TRAP 6	S00°26.228'	E035°48.034'	2929	
NB POL TRAP 7	S00°26.224'	E035°48.044'	2929	
NB POL TRAP 8	S00°26.246'	E035°48.051'	2930	
NB POL TRAP 9	S00°26.259'	E035°48.062'	2929	
NB POL TRAP 10	S00°26.282'	E035°48.032'	2932	Inside cedar
NB POL TRAP 11	S00°26.221'	E035°47.888'	2929	River bank
NB POL TRAP 12	S00°26.188'	E035°47.979'	2929	Sedge only. <b>Coring site</b>
NB POL TRAP 13	S00°26.190'	E035°47.959'	2928	
NB POL TRAP 14	S00°26.197'	E035°47.940'	2928	Sedge
NB POL TRAP 15	S00°26.218'	E035°47.922'	2927	
NB POL TRAP 16	S00°26.199'	E035°47.903'	2927	
NB POL TRAP 17	S00°26.178'	E035°47.889'	2926	Sedge/grass
NB POL TRAP 18	S00°26.175'	E035°47.906'	2925	Grass
NB POL TRAP 19	S00°26.176'	E035°47.923'	2927	Grass
NB POL TRAP 20	S00°26.177'	E035°47.935'	2925	Sedge
NB POL TRAP 21	S00°26.163'	E035°47.947'	2925	
NB POL TRAP 22	S00°26.150'	E035°47.940'	2926	
NB POL TRAP 23	S00°26.141'	E035°47.931'	2925	Sedge/grass
NB POL TRAP 24	S00°26.133'	E035°47.919'	2925	
NB POL TRAP 25, 26, 27	S00°26.121'	E035°47.908'	2928	Sedge/grass/heath
NB POL TRAP 28, 29, 30	S00°26.053'	E035°47.823'	2933	Cypress/grass/heath. Hard soil. Stake 29&30 were 50cm.
NB POL TRAP 31	S00°26.268'	E035°47.856'	2923	